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Forest Pest Management

Pacific Southwest Region

Insect and Disease Input to the Placer Big Trees Grove Analysis

Foresthill RD, Tahoe NF
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Summary

The desired state of forest health, in relation to insects and pathogens, is the condition in which these agents do not threaten ecosystem structure and function and/or management goals and objectives. Some of the old conifers within the Placer Big Trees Grove are showing signs of stress and a large number have died in the last decade as a result of stress. This stress primarily has resulted from past fire suppression, overstocked stands and protracted drought periods. Regular recurring natural fire would have kept most of the present understory (shrubs, conifers, and hardwoods) from becoming established and competing with the old conifers. These conditions have resulted in an increase in susceptibility to insects and pathogens, and stress particularly during protracted drought periods.

Conifer mortality occurred within the Placer Big Trees Grove during the early 1990's. The mortality was associated with several years (1987-1993) of inadequate moisture levels, bark beetle attacks, and overstocking. The bark and engraver beetles operating in the Placer Big Trees Grove are native and have coevolved with their host species. These disturbance agents are often inconspicuous, except during periods when their subsequent damage becomes apparent over large areas. Bark beetles and engraver beetles are fairly host specific, which facilitates in determining the cause of tree mortality. White fir mortality is associated with attacks by the fir engraver beetle. In this area mountain pine beetle typically attacks sugar pine and the western pine beetle attacks ponderosa pine. Drought, root diseases, mistletoes, and the fungus which

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causes white pine blister rust, reduce individual tree vigor and natural defenses. These agents can cause conifer mortality and/or predispose trees to successful bark beetle attacks.

Forest health restoration activities provide an opportunity to restore the resistance and resilience of ecosystems to natural stresses such as drought and bark beetle attacks. Management alternatives such as thinning can increase the health and vigor of residual trees, enable the growth of trees adapted to the site and create/enhance tree species diversity, thus lowering susceptibility to damage caused by insects and pathogens.

EXISTING CONDITION

Conifer mortality has increased over the last decade within the Placer Big Trees Grove. All size classes of pine were affected but mortality was most apparent in the large overstory trees. Some of this mortality is bark beetle related. Many large dead conifers contained large dwarf or true mistletoe brooms which contributed to the stress of the trees. Additional tree mortality should be expected within the next decade, particularly during dry years.

Historically, the most significant effect on infested areas in California has been conifer mortality associated with severe moisture stress. Conifer mortality tends to increase whenever winter precipitation is less than about 80% of normal. Trees stressed by inadequate moisture levels have their defense systems weakened to the point that they are highly susceptible to attack by bark, engraver and wood-boring beetles. Inadequate moisture levels combined with overstocked stands often leads to unacceptable levels of conifer mortality. Within the Placer Big Trees Grove the majority of the mortality is in the large overstory pines. In some cases these trees cannot compete with the dense understory vegetation for limited resources, and therefore; become stressed and more susceptible to bark beetle attacks.

Bark and engraver beetle-related mortality occurs primarily in small groups with the pine bark beetles or as single trees scattered over a large area with the fir engraver. Successful attacks by the pine bark beetles (western and mountain pine beetles) result in tree mortality. Successful attacks by the fir engraver (in white fir) can result in top-kill, branch kill, patch kills along the bole and/or whole tree mortality. In general, mortality occurs in overstocked stands, however, during periods of protracted drought, mortality may be expected to occur throughout various stocking regimes. Effects and impacts resulting from bark beetles may include the following: individual tree mortality, openings that vary in size, less trees per acre, reduced canopy closure, an increase in standing dead and down woody material, an increase in fuel load, an increase in decomposition and nutrient cycling, increase species diversity/decrease species diversity, increase in snags and cavity nesting opportunities and a change in species composition.

The importance or significance of these effects and impacts depends on their severity and extent and how they affect (positively and/or negatively) ecosystem structure and function (desired condition) and specific management goals and objectives. The effects of insects and pathogens can be used as an indicator of forest and ecosystem health.

Field Survey Information

The following information is based on field surveys conducted in June and July 1999 by FPM, and on information provided in the 8/18/99 Forest Inventory and Analysis (FIA) summary provided by

the Foresthill Ranger District. Mortality of old growth conifers in the Placer Big Trees Grove is high. Ten percent of the conifers in the grove (based on basal area) have died in the last decade and 85 percent of this mortality has occurred in conifers with a mean DBH of close to 30 inches. There are approximately 5 old growth conifer snags standing and 20 down logs per acre in the Placer Big Trees Grove. Most of the snags died over five years ago, which indicates that the mortality occurred during the protracted period of below normal precipitation, which occurred in northern California in the early 1990's.

The high mortality in the overstory indicates that the conifers in the Placer Big Trees Groves are overstocked and stressed. In the past decade, approximately 5 of 13 large old growth conifers per acre died, representing 23 sq.ft. of basal area. Since the basal area growth in the grove is 31 sq.ft. each decade, we might expect that at least half of the old growth conifers will die during the next protracted drought if nothing is done to reduce current overstocking. Much of the overstocking is present in the understory (430 trees per acre in the understory and 77 tpa in the overstory). In addition, the FIA analysis does not account for the presence of shrubs, grasses and forbs in the understory, which also compete with the overstory trees.

Historically, naturally occurring wildfire would have regularly underburned the Placer Big Trees Grove and removed some of the trees and vegetation that have become established in the last century. Fire exclusion policies have allowed the grove to become crowded with young trees and vegetation that normally would not be present. An observer only has to look at the standing old growth in the Placer Big Trees Grove, and mentally remove most of the other trees and shrubs, to get an idea of what the grove looked like 100 years ago. In 1900, the grove probably had 15 to 20 openly growing old conifers on average per acre. On the forest floor, there might have been up to 70 young conifer seedlings, saplings and trees, and 5 oak trees per acre. Most of the smaller conifer reproduction and shrubs in the understory typically would have been killed by the fires that would have underburned the grove in the 20th century without fire suppression. An open condition in the Placer Big Trees Grove would have supported the health and vigor of the old growth conifers, protected their crowns and boles from killing by wildfire, and provided good sites for giant sequoia seed to germinate and grow.

The following is intended to be a general discussion of the insects and pathogens related to the mortality (by tree species) in the Placer Big Trees Grove.

Giant Sequoias

Specimen giant sequoias are the key feature in the Placer Big Trees Grove. The grove consists of six standing and two fallen naturally occurring giant sequoias. Natural regeneration of giant sequoias in the grove is limited to one sapling. Artificial regeneration consists of several planted seedlings and a small patch of sequoia trees that were planted in 1951 by the Lions service organization. All plantings were with seedlings grown from seed collected elsewhere, which have the potential to contaminate the natural gene pool of the sequoias in the grove. All the live giant sequoias in the Placer Big Trees Grove, except for the smallest seedlings appear healthy at this time.

Some of the standing and fallen specimen giant sequoias, as well as many of the old growth conifers, have fire scars. This indicates that fire was a natural component of the grove. As mentioned above, fire was instrumental in the Placer Big Trees Grove in keeping the understory from competing with the old growth conifers. In addition, fire provided favorable sites for regenerating the giant sequoias. Currently, only one naturally occurring sequoia sapling is now growing in the grove and it is unlikely that it will grow into large sequoia because of current stand conditions. The lack of natural regeneration from the specimen giant sequoias is of particular concern because only 6 of the original 8 old sequoias in the Placer Big Trees Grove are still standing. Since it will take over 1,000 years to grow replacement specimen giant sequoias, the six standing specimen giant sequoia trees in the Placer Big Trees Grove may fall over before replacements can be grown.

Giant sequoias are subject to the same natural forces (including insects and diseases) as other tree species. The main forest health condition adversely affecting the giant sequoias in the Placer Big Trees Grove is overstocking. The competing vegetation in the understory is stressing the associated old growth conifers, preventing natural giant sequoia regeneration, and presenting ladder fuels, which threaten all the old growth conifers, including the specimen sequoias. Root disease is a concern in the Placer Big Trees Grove since it can weaken the supporting roots of the specimen giant sequoias. Annosus and armillaria root diseases are discussed in detail below. The following general discussion on insects and diseases found on giant sequoias is taken from a paper presented by Douglas Piirto at the Giant Sequoia Symposium in Visalia, CA on June 25, 1992.

Scientists have been recording insect and disease associations with giant sequoia for some time. However, the significance, ecological role, and influences that affect these organisms are not well understood. Of 143 species of insects found in one study with giant sequoias, 4 were found on seedlings, 32 in downed limbs, 3 in standing dead wood of living sequoias, and 114 were found only in the canopy of living trees. Several insects such as termites, defoliators, bark beetles, wood borers and carpenter ants can be very destructive to young and old growth giant sequoias. Relatively little work has been done on damaging biotic and abiotic agents of seed, seedlings, saplings and young growth giant sequoia trees. Cone and seed molds, damping off fungi and root rot fungi are suspected as being major factors in preventing seedling establishment in native giant sequoia stands. These fungi have been shown to reduce seed viability and to prevent seedling establishment in undisturbed duff and litter within coast redwood stands. The role these fungi play in native giant sequoia stands is not known.

One study evaluated the causes for tree failure in 33 old growth giant sequoia trees. Of the 33 failures, 7 fell mainly because of poor footing, 22 because of the failure of decayed roots, and 4 because of stem breaks. All but two of the trees (both fell because of poor footing) had decay in either the stem or roots. Carpenter ants were found in 16 trees but appeared to contribute to failure of only 6. Fire scars were present on 27 trees and 26 fell to the fire-scarred side.

Many Basidiomycetes are responsible for the decay observed in giant sequoia trees. *Heterobasidion annosum*, the cause of annosus root disease, has been frequently observed in both the upper and lower stems of recent tree failures of giant sequoias. Recent research appears to confirm that *H. annosum* may spread via root contacts from white fir to giant sequoia. Armillaria root disease, caused by *Armillaria mellia*, is receiving increasing attention as being an important

pathogen of giant sequoia both within and outside the native range of giant sequoia. Forty-year-old giant sequoias planted around the Foresthill Seed Orchard showed thin crowns and groups of 30 - 50 ft. tall trees were easily pushed over. Indications were that armillaria root disease may have been responsible for the sequoia mortality at Foresthill. Giant sequoias appear to be especially vulnerable to *Armillaria sp.* when planted outside their native range near oaks or other hardwoods. In addition to root disease, sequoias planted outside their native range can be severely damaged by a canker fungus, *Botryosphaeria sp.* This canker disease is easily recognized by dead foliage in the crowns and is commonly found in ornamental plantings.

Fire suppression has altered stand development in the giant sequoia-mixed conifer ecosystem, resulting in changes in stand density and species composition. Prescribed burning can also have beneficial and detrimental effects. Damaged roots, stems, limbs and other tree tissues serve as entrance courts to pathogen and insect attack. It is important for managers of giant sequoia groves to take appropriate protective measures to minimize the deleterious effects of forest management practices on the giant sequoia-mixed conifer ecosystem.

Annosus root disease

A conk of annosus root disease was identified in a decayed white fir stump in the Placer Big Trees Grove. Since *H. annosum* is usually confined to the heartwood of true firs, any of the older white fir in the grove may be infected. *H. annosum* is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos sp.* and *Artemisia tridenta*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Annosus root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forest land in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and in recreation areas, depletion of vegetative cover and increased probability of tree failure and hazard.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root contact into the root systems of adjacent live trees, resulting in the formation of enlarging disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

H. annosum in western North America consists of two intersterility groups, or biological species, the 'S' group and the 'P' group. These two biological species of *H. annosum* have major differences in host specificity. All isolates of *H. annosum* from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita have, to date, been of the 'P' group. Isolates from true fir and giant sequoia have been of the "S" group. This host specificity is not apparent in isolates from stumps, with the 'S' group being recovered from both pine and true fir stumps. This data suggests that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

One old declining white fir tree is growing approximately 50 feet from the Pershing tree (one of the six specimen giant sequoias in the grove). It is possible that this white fir has annosus root disease since its crown appears unhealthy and annosus root disease has been found in a white fir stump elsewhere in the Placer Big Trees Grove. The roots of the Pershing tree have already been associated with those of the nearby white fir for over a century so it is likely, yet not certain, that the Pershing tree is infected with annosus root disease. There is no action that can be taken at this point to protect the Pershing tree from *H. annosum.* Removing the old declining white fir from near the Pershing Tree, and keeping white fir from growing around all the specimen sequoias is a good way to keep annosus root disease from infecting healthy sequoia roots. Historically, recurring natural fire would have killed most of the young conifers around the giant sequoias and prepared a seedbed where young sequoias could become establish. The fire would have thinned the conifers in the grove and given the young sequoias growing space. When cutting any conifer near a giant sequoia, it is necessary to treat the freshly cut stump with Sporax, the borax compound that is registered to prevent annosus root disease from entering healthy conifer roots through stumps. Treatment of conifer stumps 12 inches or greater in diameter is highly recommended for chainsaw felling. When mechanical fellers are used which cut the stumps near the ground, the minimum diameter should be reduced to 8 inches.

White fir

White fir is found as a component of the mixed conifer type making up the Placer Big Trees Grove. In some areas dense stands of white fir in the understory are out-competing the large overstory pines. Regeneration of pine is almost absent in the grove as the more shade tolerant conifers are better competitors. White fir is a more short-lived species and does not tolerate extended periods of moisture stress compared to ponderosa pine. White fir top kill and mortality, although not extensive, has been occurring within the grove for several years now. The mortality over the past decade is a result of moisture stress, fir engraver attacks, and overstocking.

Fir engraver

The fir engraver, *Scolytus ventralis*, is the most important bark beetle attacking white fir in California. It attacks and can kill nearly all age classes. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the

tree. Trees greater that 4 in. dbh are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without first killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

There does not seem to be a recognizable pattern of fir engraver outbreaks in California. When outbreaks do occur, their simultaneous occurrence in many widely separated localities causes severe damage to forests. Sporadic outbreaks have been recorded in California and Oregon at least once a decade since 1925. Dry sites, drought, and root disease play important roles in the susceptibility of true fir to fir engraver, and they are probably the most important factors influencing the food supply for beetles. Under adequate moisture regimes, overstocking of fir stands and high infection rates by root disease are the principal factors involved in predisposing trees to attack by fir engraver.

Ponderosa pine

Old growth ponderosa pine mortality has occurred in the Placer Big Trees Grove for the past decade. This mortality can be attributed to moisture stress, overstocking in some cases, and elevated bark beetle activity. The bark beetles associated with the mortality are the western and mountain pine beetles.

Ponderosa pine is susceptible to western dwarf mistletoe. Old trees are usually not adversely affected by light infections. Young ponderosa pine are often severely affected by dwarf mistletoe infections. When ponderosa pine seedlings are planted under infested overstory ponderosa pine, the young trees will eventually become infected.

No annosus root disease was found in the pine in the Placer Big Trees Grove. Annosus root disease on pine occurs elsewhere on the Forest. This root disease can easily infect conifer root systems when spores of this fungus germinate on freshly cut stump surfaces. For this reason, it is very important to treat conifer stump surfaces with a registered borate compound as soon after felling as practical. Treatment of conifer stumps 12 inches or greater in diameter is highly recommended for chainsaw felling. When mechanical fellers are used which cut the stumps near the ground, the minimum diameter should be reduced to 8 inches.

Western pine beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensively studied and has proven to be an important factor in the ecology and management of ponderosa pine throughout the range of this host species. This insect breeds in the main bole of living ponderosa pine larger than about 4 inches dbh. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe, or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latitude and elevation, there can be from one to four generations per year.

Under normal conditions the western pine beetle breeds in a few overmature trees, unhealthy trees, or in trees weakened by drought, stand conditions, or fires. The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In California, drought stress may be the key condition influencing outbreaks in that healthy trees undergo sudden and severe moisture stress can facilitate the buildup of western pine beetle populations. The thick, nutritious phloem and inner bark of healthy trees become host material for attacking beetles. Healthy trees ordinarily produce abundant amounts of resin, which pitch out or eject attacking beetles, however, when deprived of moisture, stressed trees cannot produce sufficient resin flow to resist attack. Any condition that results in excessive demand for moisture, such as tree crowding, competing vegetation, or protracted drought periods; or any condition that reduces that ability of the roots to supply water to the tree, such as mechanical damage, root disease, or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predaceous beetles and low winter temperatures are natural control agents.

Sugar pine

Mortality is common in old growth sugar pine in the Placer Big Trees Grove. The mortality can often be attributed to attacks by the mountain pine beetle. The primary concern, however, with sugar pine in the grove is dwarf mistletoe, *Arceuthobium californicum*. Many large dwarf mistletoe brooms are present in the old sugar pine trees and snags in the grove. A combination of factors including overcrowding, dwarf mistletoe, and a protracted period of below normal precipitation has led to successful mountain pine beetle attacks ultimately causing tree mortality. Much of the overcrowding in the understory is conifer regeneration and shrubs and would have historically been eliminated by frequent natural underburns.

Mountain pine beetle

The mountain pine beetle, *Dendroctonus ponderosae*, attacks the bole of sugar pines larger than about 8 inches dbh. The food supply regulates populations of the beetle. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather, affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include low winter temperatures, nematodes, woodpeckers, and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and mortality increases.

Dwarf Mistletoe

Dwarf mistletoes (*Arceuthobium sp*) are parasitic, flowering plants that can only survive on living conifers in the *Pinaceae* family. They obtain most of their nutrients and all of their water and minerals from their hosts. Heavy dwarf mistletoe infestation and/or many large brooms on a tree can sufficiently weaken it during drought periods to predispose the tree to bark beetle attack.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and are forcibly discharged from the aerial shoots. The seed is covered with a sticky substance and adheres to whatever it

contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence, that long distance spread of dwarf mistletoe, is occasionally, vectored by birds and animals. Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density.

Dwarf mistletoes are easy to identify because they are generally exposed to view within the crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached, and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

Incense Cedar

There are a number of old growth incense cedar snags in the Placer Big Trees Grove. Some of the old incense cedar trees and snags have brooms caused by the true mistletoe, *Phoradendron libocedri*. This parasitic plant can weaken its host and predispose the infested trees to mortality from other factors. Direct tree mortality as a result of insect attack is not common in incense cedar. The primary species of beetles that attack incense cedar are not considered to be aggressive tree killers, however, their impact, combined with drought stress and mistletoe infestation can cause mortality. Most of the observed mortality in the grove is a result of competition from the understory vegetation. The overstocking in the understory is a result of excluding natural fire from the grove.

DESIRED CONDITION

Forest Health Restoration

The desired state of forest health is the condition where biotic and abiotic influences do not threaten resource management objectives and provide desired, sustainable ecosystems. In part, a healthy forest is one is which the environmental effects of insects and pathogens are maintained within acceptable limits and do not result in unacceptable impacts on the sustainability of the ecosystem structure and function or specific resource management goals and objectives. Resource management objectives reflect the many uses and values within the analysis area including wildlife, recreation, timber, grazing, water, and wilderness, and must take into consideration ecological limitations and processes. Dependent upon management objectives, the acceptable level of insect and pathogen-related activity may vary greatly.

The structure and composition in the Placer Big Trees Grove have changed since European settlement in response to both management activities and climatic events such as periodic drought. A decline in forest health has resulted from these changes, as indicated by the increased mortality in the old growth conifers. An accelerated effort is needed to restore overall forest health so that future disturbance events such as drought, fire or insect outbreaks, fall within the ability of the ecosystem to absorb and thereby maintain their biological integrity and diversity.

Forest health restoration activities should take an ecological approach to multiple-use management. Objectives may include:

* Restoring the resistance and resilience to natural stresses.
* Decreasing the risk of catastrophic fires.
* Modifying the vegetation to reduce potential damages caused by insects and disease.

Management Alternatives

The following alternatives are general ones that can be applied to the Placer Big Trees Grove.

(1) <u>No action</u> - Overstocked stands in general will tend to have higher levels of bark and engraver beetle-related mortality. The basal areas in stands will continue to increase as the trees grow. Periodic droughts in California increase the probability, that some of the trees in the overstocked stands will be attacked by bark beetles. Although some mortality may be desired for snags, small openings, and for future down woody debris, the no action alternative will most likely result in unacceptable levels of mortality in the oldest conifers in the grove.

The direct result of an increase in tree mortality in the Placer Big Trees Grove is fewer large, old growth trees. The growth of understory trees and vegetation is competing with the old overstory conifers as evidenced by the general decline of the crowns of many of the oldest trees in the grove.

(2) <u>Thinning Overstocked Stands</u> - Management activities that promote tree health and vigor also reduce the susceptibility to successful bark beetle attack.

Thinning is perhaps the most critical silvicultural treatment available to restore and maintain forest health. Thinning from below reduces flammable fuels, creates growing space for trees, and can provide a receptive seedbed for giant sequoia seed. Silvicultural prescriptions designed to reduce basal areas should result in lower levels of bark beetle-related mortality in the future. Mortality would continue to occur and fluctuate in response to the amount of available moisture, but at levels that, through time, would more closely approximate naturally occurring mortality. Thinning would result in, a decrease in the need to enter stands to conduct salvage operations, a decrease in the amount of fuel loading, and a reduction in the number of hazard trees. When harvesting conifers, it is important to treat the freshly cut stump surfaces with a registered borate compound to prevent infecting the root systems with annosus root disease.

Snags, down woody material, and nutrient cycling would occur at more natural levels. The improved growing conditions should result in reduced mortality of large diameter trees and an increase in mid-diameter trees available to grow into large diameter classes. Selecting for

diversity of residual tree species during thinning is desired as bark beetles are fairly host-specific and diversity should guarantee that some trees will remain alive during elevated stress periods. Dependent upon slash treatment, there would be some level of risk of subsequent top-kill and/or whole tree mortality to residual conifers due to pine engravers that reproduce in green slash.

(3) Reintroduce Fire – Historically, natural fire kept the understory vegetation in the Placer Big Trees Grove at lower densities. With fire exclusion over the last century, many understory trees and shrubs have become established in the grove. This vegetation (trees, shrubs, grasses and forbs) is competing with the old growth conifers for moisture and light. During the protracted drought in the early 1990s, many old growth conifers in the grove died as a result of moisture stress, which in combination with various diseases, weakened the trees and allowed various bark beetles to successfully attack.

In order to recreate the ecosystem that existed in the Placer Big Trees Grove before Europeans arrived, fire needs to be reintroduced to the grove. Some pre-treatments, including thinning and removal of the shrub and fuel ladders and litter from around residual trees would be required prior to introducing fire back into the ecosystem.

Underburning can damage some residual trees to the extent that they become more susceptible to bark beetle attacks. Trees that receive cambial and/or foliage damage may be at increased risk to bark and/or engraver beetle attack that would persist until the trees recover their vigor.

Fires of sufficient severity to scorch the bark, cambium and foliage of pine trees produce types of injury, which make certain trees more attractive to the bark and/or engraver beetles. Many trees, which have been only moderately injured by the fire and are capable of recovering may be attacked and killed by beetles after a fire. The attraction of fire-injured trees often causes a concentration of beetles within a burned area, which lasts for one or two season following a fire. While fire-injured trees can attract bark beetles in considerable numbers they do not always afford favorable breeding conditions for new broods. Some of the factors involved in post-fire bark beetle attacks are: level of stress of trees prior to the fire (ie. drought-stressed), bark beetle populations levels prior to the fire and timing of salvage operations. Fires that result in cambium damage create open entry courts for pathogens. Several brown and white rots have been identified as being introduced to trees through fire scars.

It may be useful to remember that one hundred years ago the Placer Big Trees Grove contained approximately 20 old growth conifers in the overstory and 77 trees of all sizes in the understory. This is an extremely open condition, yet one that can keep the large trees in the grove resilient and resistant to insects, diseases and fire. By ‘opening up’ the grove and using frequent prescribed burns to keep the vegetation suppressed giant sequoias will grow from seed produced by the remaining six specimen trees in the grove. With a minimum of competition, the sequoia trees will grow fast and provide replacement specimen giant sequoias for the next millennium.